CMOS IMAGE SENSOR WITH EMBEDDED MICRO-LENSES

BACKGROUND

Description of Related Art

The cost of CMOS image sensor digital camera systems is being reduced through the use of smaller pixel sizes. Ideally, the reduction in size of CMOS image sensor pixels can be achieved with an improvement in image resolution and without a significant decrease in signal to noise ratio. As image sensor pixel sizes continue to decrease, there is a risk of a reduction in optical efficiency, as well as an increase in optical crosstalk between adjacent image sensor pixels.

One solution to the optical crosstalk between adjacent image sensor pixels is to dispose micro-lenses on the color filter layer of the CMOS image sensor. A typical micro-lens may be a single element with one plane surface and one spherical convex surface to refract the incident light, and micro-lenses is generally with a diameter less than 1 mm and often as small as 10 μm. Each of the spherical convex surfaces has to align with the photodiodes under the color filter layer for gathering incident light into the photodiodes. However, since the micro-lenses above the color filter layer and the layers under the color filter layer are formed in different modules or even manufactured by different manufacturers, alignment errors may occur, and the problem of the alignment error will be more serious as the pixel size is decreased.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional diagram of a backside illuminated CMOS image sensor having embedded micro-lenses according to some embodiments of this disclosure.

FIG. **2**A is a flow chart illustrating a process of manufacturing a backside illuminated CMOS image sensor device shown in FIG. **1** according to some embodiments of this disclosure.

FIGS. **2**B-**2**C are cross-sectional diagrams illustrating the manufacturing process in FIG. **2**A, according to some embodiments of this disclosure.

FIG. **3**A is a flow chart illustrating a process of manufacturing a backside illuminated CMOS image sensor device shown in FIG. **1** according to some other embodiments of this disclosure.

FIGS. **3**B-**3**C are cross-sectional diagrams illustrating the manufacturing process in FIG. **3**A, according to some embodiments of this disclosure.

DETAILED DESCRIPTION

In the following detailed description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the disclosed embodiments. It will be apparent, however, that one or more embodiments may be practiced without these specific details. In other instances, well-known structures and devices are schematically shown in order to simplify the drawing.

Accordingly, in this disclosure, micro-lenses were designed to be embedded respectively under color filter sheets to gather incident light to irradiate on each photodiode in the pixel array of a CMOS image sensor to solve the problem of alignment error between the micro-lenses and the photodiodes in the pixel array.

FIG. **1** is a cross-sectional diagram of a backside illuminated CMOS image sensor having embedded micro-lenses according to some embodiments of this disclosure. In FIG. **1**, a substrate **100** has a pixel array formed on a front surface of the substrate **100**. The pixel array includes a plurality of photodiodes **110** in the substrate **100**. A dielectric layer **120** and a buffer oxide layer **130** are sequentially disposed on the back surface of the substrate **100** and thus cover the backside of the pixel array.

The buffer oxide layer **130** has a plurality of concave surfaces **135** positioned respectively align with each photodiode **110** in the pixel array. Pluralities of micro-lenses **140** are respectively disposed on the concave surfaces **135**. Accordingly, these micro-lenses **140** have a convex-like or hemispherical cross section to confine incident light **170** to irradiate on the photodiodes **110** and thus can replace the conventional micro-lens layer.

Next, a grid layer **150** is disposed on the buffer oxide layer **130** and has a plurality of openings **155** exposing the micro-lenses **140** respectively. Color filter sheets **160** are respectively disposed in the openings **155** of the grid layer **150**.

According to some embodiments, the dielectric layer **120** can be made from a dielectric material having a dielectric constant greater than or equal to silicon oxide to protect the photodiodes **110**. For example, the dielectric layer can be a silicon oxide layer, a silicon nitride layer, or a high-k dielectric material.

According to some other embodiments, the micro-lenses **140** can be made from a transparent material having a refractive index greater than the refractive index of the color filter sheets **160** and smaller than the refractive index of the buffer oxide layer **130**. For examples, the transparent material can be made by glass, or a transparent polymer.

According to some other embodiments, the grid layer **150** can be made of silicon oxide or metal. For example, the metal can be Al, Cu, Cr, or an alloy of Cu and Al.

According to yet some other embodiments, for avoiding total internal reflection of the incident light **170**, the refractive indexes of the color filter layer **160**, the micro-lenses **140**, the buffer oxide layer **130**, the dielectric layer **120**, and the substrate **100** have better to be arranged in an order of from small to large. That is, the refractive index of the color filter layer **160** is better to be smaller than the refractive index of the micro-lenses **140**. The refractive index of the micro-lenses **140** is better to be smaller than the refractive index of the buffer oxide layer **130**. The refractive index of the buffer oxide layer **130** is better to be smaller than the refractive index of the dielectric layer **120**. The refractive index of the dielectric layer **120** is better to be smaller than the refractive index of the substrate **100**.

According to some other embodiments, for optimizing the light gathering effect, the focus length of the micro-lenses **140** is better to be equal to the distance from the micro-lenses **140** to the photodiodes **110**. Therefore, the incident light **170** can be focused on the photodiodes **110**. The factors affecting the focus length include the refraction index of each layer between the micro-lenses **140** and the photodiodes **110**, and the radius of curvature of the micro-lenses **140**.

FIG. **2**A is a flow chart illustrating a process of manufacturing a backside illuminated CMOS image sensor device shown in FIG. **1** according to some embodiments of this disclosure. FIGS. **2**B-**2**C are cross-sectional diagrams illustrating the manufacturing process in FIG. **2**A. Therefore, FIGS. **2**A-**2**C are referred below at the same time.